Multi Eruption Solar Energetic Particle Events Observed with SOHO/ERNE

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A combination of many Solar energetic particle (SEP) events, each one of which is associated with a single eruption, can create one complex intensity-time profile, that will result in masking the observation of the first injected particles detected near Earth for each participated eruption. We defined such SEP events as Multi Eruption Solar Energetic Particle (MESEP) events. We have investigated the intensity-time profile of 333 solar energetic particle events during the operation time of SOHO mission and studied the associative solar eruptions (CMEs and solar flare) from the starting time of each event till the end. We found that most of the events have multi eruption phenomena which might or might not affect the intensity-time profile. We found that it is possible to know the real effect of some of the eruptions during the whole duration of the event, even if their effect as masked by the first eruption, by studying the widest possible energy range, the $^4He/P$ ratio and the anisotropy.

Introduction

Since the 1970's Solar energetic particle (SEP hereafter) events have been well known to be connected with two major coronal phenomena: solar flares and Coronal Mass Injections (CMEs hereafter) (e.g., [3, 10, 15, 16]), and with interplanetary shocks [17, 18]. The observation of the first non-scattered relativistic particles [20] is one tool to establish the connection between sudden rise in the intensity-time profile for many particle species which occur after flares or CMEs. Note that these measurements are background dependent and unless the background of the intensity-time profile is clear enough and not masked by previous events, the exact association of the SEP events with the eruption cannot be accurate. In this manner it is not possible to know whether the CMEs or solar flare which occurred after the first eruption have injected/accelerated any SEPs since intensity-time profiles are masking the possible effect of the SEPs related to such eruptions. Furthermore, even in some single eruptive SEP events we can find more than one acceleration phase (e.g., [1, 2]). Cane et al. [5] found correlation between long-low frequency type III radio bursts and SEP events. During one event we might observe many such radio emissions and hence multi-eruption sources cannot be ruled out.

However, many earlier studies indicate the general features of CMEs and solar flares which are associated with SEP events whether they are impulsive or gradual (e.g., [6]). It is well known that the CME speed and the SEP intensity are well correlated [12]. The same study concludes that no fast CMEs with widths less than 60° are associated with SEP events. And nearly all fast halo CMEs are associated with SEP events. On the other hand, the indication of the solar flare X-ray features related to SEP events has been established earlier (e.g, [3]). In general we know now that CMEs with speed >500 km/s and angular width > 50° can be possibly related to injection/acceleration of SEP and long duration C, M, X class solar flare or impulsive M and X class can also be related to injection/acceleration of SEP.

A gradual SEP event might not be due to one single eruption, CME or solar flare. The continuity of high intensities due to coronal or interplanetary shock waves might come from several eruptions, which might end in showing one single prolonged intensity-time profile. In such case a continuing intensity-time profile can be due to Multi Eruption SEP (MESEP) event. Whether those eruptions are effective or not this issue needs further examination. Note that the starting of an event might be due to a CME associated with a solar flare. Due to complexity of distinguishing between CMEs and flares in particle acceleration is a non-solved problem, since both eruptions occur in general in same active region and same time, we rather account such kind of events as single eruptive.

In several studies (e.g., [4]) the ratio of different compositions has revealed the differences in seed population. Cliver [6] and Reames [14] have used $^4He/P$ ratio to identify different classes of SEP events. Thus the changing in the $^4He/P$ ratio during the specific period might be related to different tubes of SEPs accelerated by different eruptions. On the other hand, studying the history of particle transport might reveal the different sources for SEP acceleration. Moreover, Cliver et al. [7] indicate that changes in SEP time profile is due to more than one SEP-effective shock or other accelerator at work.

In this study we examine (SEP) events which have an intensity-time profile masking the effect of later eruptions in the event. The examination of possibly widest range of energy channels with the investigation of $^4He/P$ ratio and anisotropy might help to determine whether those eruptions are effective or not.

Data analysis

We have used intensity-time profile for proton and helium particles provided by the two ERNE detectors, High Energy Detector (HED) and Low Energy Detector (LED) (Torsti et al. [19]). We examine the intensity-time profile through two ways.
I) The linear profile provided by *http://www.decent.fi/soho/index.php*.
II) The logarithmic profile provided by *http://www.srl.utu.fi/erne_data/*.
In the linear fit the changes during high-intensity periods are more visible than in logarithmic view and thus it might be easier to see if the changes were due to local effect or they have a velocity dispersion and belong to an event on the Sun. Logarithmic scale is used by most researchers and gives the general view of the event.

We took the widest possible energy range starting from 1 MeV up to 116 MeV for each event to see the differences in the profile in each channel and whether it is the same for all events or we have different individual cases or groups. We considered an event to be a MESEP event if the logarithmic proton intensity-time profile does not reach the background level during a certain period in many energy levels (some might do) and we observed many eruptions on the Sun during that period. We divided the MESEP events according to the energy levels to three types 1) low energy events (weak events) which produce particle of <10 Mev and with maximum intensity of not less than $10^{-2}/(\mathrm{cm}^2\ \mathrm{sr\ s\ MeV})$. 2) Mid energy MESEP events, which produce particles of <30 MeV. 3) High energy MESEP events, which produce particles of >30 MeV, and to four types according to the intensity-time profile in the low and high energies. Type 1) where the low-energy channels show peaks and the peaks fade down or disappear in the higher energy channels leading to less peaks or a single peak. Type 2) where both low and high energy channels show the peaks. Type 3) where the high energy channels show peaks that low energy channels does not show. Type 4) where both low and high energy channels does not show any obvious peaks (see Fig.1).

We used the SOHO/LASCO catalog at *http://cdaw.gsfc.nasa.gov/CME_list/UNIVERSAL/* to determine the number of CMEs related to those events, taking into consideration CMEs with >500 km/s and GOES data search engine for solar flare, taking in consideration M, X and long duration C class flares. We have selected some events and look for: (i) Any changes in any energy channel close in time to the eruption, especially if the changing create peaks that shows a rise intensity closer to the background like in the beginning of the event. (ii) The measurements for the $^4He/P$ ratio and comparison of it to the time location of the eruption. The boundary of ratio changing before and after the time of the associated eruption should not be less than factor of two. (iii) Possible anisotropy measurement and compare the changing to the associated eruption. If any of the above measurements fit with any eruption we can assume that this eruption has a SEP enhancement during the event. We also look at the stream interactione region events list by Jian et al. [8] and the interplanetary coronal mass ejection list by Jian et al. [9] to find possible association with these two types of events. In the future we intend to verify this method and apply it to all events.

Results

We went through the SEP events' intensity-time profiles from May 1996 till March 2007. A set of 333 SEP events observed by ERNE was uploaded from the web list *http://www.decent.fi/soho/index.php*. We searched in each event for associated CMEs and solar flares during the time when the intensities are prolonged and make one continued profile in many energy channels. Events typically start with a sudden rise in the intensity over the cosmic ray background due to an eruption launched on the Sun and the majority of the SEPs start to be injected in the corona at heights below ∼2 $R_\odot$[13]. The bulk of ions of any energy is accelerated by the bow shock of the CME while it travels through the high corona (>5 $R_\odot$[11]). Thus, the

first associated eruption can be easily detected with observation of the first non-scattered energetic particles independent of acceleration mechanism/release height.

In many events when the acceleration is prolonged for many days, especially during the maximum activity in the Sun, we observe frequent eruptions each day. We might not be able to see the first sudden rise in the intensity nor even the decay. Among the 333 events 268 were observed with many eruptions that associated but not necessary participated in one intensity-time profile. We excluded events that are either clearly due to only one solar eruption (in addition to those with no solar signatures).

Among 65 non-MESEP events about 47 (72%) were low energy events. Among 268 MESEP events only 30 (11%) were low energy events, leaving a conclusion that the MESEP events are mostly powerful long duration events. Thus we put the MESEP events according to the maximum accelerated energy particles into three types: High, Mid and Low. The major portion ($\sim$70%) of the MESEP events were High energy events - 189 from 268 with energies >30MeV. The Mid energy events 20-30 MeV were 49 from 268 events ($\sim$19%) and the Low energy events <20 MeV were only 30 events ($\sim$11%).

The intensity-time profiles are not the same in all the cases of the MESEP events. It is possible to notice a few types of common features among them. We have chosen four types (see Fig.1) according to the following common features in the intensity-time profile for the 268 MESEP. Type 1, where we normally observe in the low energy channels many peaks which might or might not be related to events on the Sun or in the interplanetary medium, but in the high energy channels show only a few single peaks or even one peak. This means that some eruptions which are contributing to the events produce less higher energetic particles than those which maintain the production or the events have prolonged intensity profile in the low energy, which is typical. This type was the most common among the MESEP intensity profile, $\sim$40% (109 from 268). Type 2, where we observe in both high energy channels and low energy channels almost the same changing in the intensity profile. This type contains $\sim$21% (56 from 268) of the MESEP events. Type 3, where we observe many peaks in the high energy channels but not in the low ones. This type is less common among the MESEP events and contain only $\sim$16% (42 from 268). Type 4, where we can not see any obvious peaks in both high and low energy channels. This type contain $\sim$23% (61 from 268) of the MESEP events.

In the first three types it is possible to figure out some of the hidden eruptions under the prolonged intensity profile if we take all the possible observed energy channels, since some channels, either low ones or high or both, have some obvious peaks that might relate to those hidden eruptions. In those cases we can assume that the eruptions are effective and have accelerated SEPs (see Fig.1). But also in certain periods during the events we might observe many eruptions that do not have any related features in the intensity-time profile. Those eruptions and the eruptions associated with type 4, where no peaks are observed, are the most obscure cases in the SEP acceleration. If we can not see related accelerated particles through the intensity-time profile then how can we know whether this eruption has injected or accelerated any SEPs?

We have chosen arbitrary events where we have an analysis of anisotropy data. An anisotropic event was registered on the 11th of November starting at 9:45 with the Energetic and Relativistic Nuclei and Electron (ERNE) instrument on the Solar and Heliospheric Observatory (SOHO) (see Fig.2). The high energy detector (HED) of the ERNE instrument is pointing to the direction of θ=0°, ϕ=315° GSE, and its wide viewcone (120°x120°) is divided into 241 directional bins, from which proton and helium fluxes can be measured (see also Torsti et al. [21]). The upper left panel in Fig.2 shows the directional distribution at 9:51-9:59 UT for protons from energy range 16.9-22.4 MeV. The upper right panel shows the pitch angle distribution the directional bins form. SOHO does not have a magnetometer on board, but the supposed magnetic field direction was found by fitting a polynomial function to the pitch angle distribution (see also [22]). The direction of the found symmetry axis is pointed with a white cross and the deflection angles of 5°, 30°, 60° and 90° are marked with circles. The anisotropic flow is very narrow and anisotropy merges without significant change in the total mean flux. The horizontal panel shows an arbitrary statistical anisotropy index rising to its peak at 10 UT and after a more isotropic period it rises again. The whole event lasts for less than four hours.

The anisotropic flow of solar energetic protons of 16.9-22.4 MeV at its peak at 9:51-9:59 UT was measured by ERNE/HED instrument. Time integration of 8 minutes was used. Upper left is the instrument's viewcone with coordinates in GSE. The direction of the Sun is indicated with a small picture of a Sun left from the center of the viewcone. The full circle area with coordinate lines is the hemisphere which ERNE is pointing at, and the semi-rectangular borders indicate the borders of the viewcone. The same 241 measuring points seen on the left form the pitch angle distribution in the right panel. The direction that has been used to derive the pitch angles is indicated in the upper right corner of the panel. The horizontal panel is the total mean anisotropy index in which values over 10 indicate significant deviation from isotropic flow.

On the other hand, the measurements of the ^{4}He/p ratio shows a clear dip at the same time of the anisotropy changes (see Fig.2). The ^{4}He/p can strengthen the assumption for a source of eruption from the Sun. In some cases anisotropy measurements by itself might indicate an influence of entering a different

magnetic tube due to the same eruption that fills many magnetics tubes. On the other hand, the ^{4}He/p ratio means that we have a source of different seed population and there are different accelerated particles at that time. This might lead us to conclude that the eruption which is associated with the changing in the anisotropy measurements and ^{4}He/p has fill a new magnetic tube with different seed population particles than the previous one. The eruption in this case was the Lasco CME which has been seen by Lasco C2 at first time on height 3.51 $R_{\odot}$ with linear speed of 639 km/s and angular width of 34° which is not wide enough as it is expected for a CME to accelerate SEPs. But the location of the CME on the solar disc at the southwest in central position angle of 259°, can make this CME a good candidate. Still this case can not be assumed as an effective CME unless we take further careful analysis. Jian et al. [9] have used the data from Wind and ACE. His list shows that the space craft has entered an interplanetary coronal mass ejection at 4:13 UT and ended at 21:00. There might be a possible existence of different tube which carries different seed population of energetic particles. In this case the change in the anisotropy is spatial and due to local effect, but the type of changing in both ^{4}He/p ratio and anisotropy suggests temporal effect from a source on the Sun. We expect to obtain this method for further investigation for the rest of the hidden eruptions of the MESEP events in the future.

Conclusions

A combination of many SEP events, each one awhich is ssociated with a single eruption, can create one complex intensity-time profile that will result in masking the observation of the first injected particles detected near the Earth for each participated eruption. We defined such SEP events as Multi Eruption Solar Energetic Particle (MESEP) events. We found among the 333 SEP events that we observed between May 1996- March 2007 the following:

1- About ∼80% of the SEP events were MESEP events.

2- The MESEP events' intensity-time profiles are observed with energetic particles from 1 up to over 100 MeV and contain three types of energy levels: High energy events with energies of >30MeV and ∼70% from total MESEP events; Mid energy events with energies of >20MeV-<30MeV and ∼19%; and Low energy events with energies of <20MeV and ∼11%, which means that the MESEP events are mostly long duration high energy events.

3- The intensity-time profile for the MESEP are of four types. Type 1, with peaks in low energy channels disappearing or getting less in high energy channels and this type contains ∼40% of the MESEP events. Type 2, with peaks in both high and low energy channels and contains ∼21%. Type 3, with peaks in high energy channels more than in low energy channels and contains ∼16%. Type 4, with no peaks in both energy channels and contains ∼23%.

4- The observation for the possible particle acceleration or injection of each participant eruption are possibly accomplished if we use: i) High range of intensity-time energy channels which might result in finding some associated features in some energy channels that might related to certain eruptions. This is possible in the first three types. ii) For the rest of the eruptions in type 4 and eruptions in the other types which are not associated with peaks in any energy channels we are not able to assume whether they participate in the acceleration or injection of energetic particles during the period of the event unless we analyzed the anisotropy and the $^{4}He/P$ ratio and find obvious association with the eruption. Hidden eruptions during the MESEP events need further investigation to provide wider and clearer view on the solar energetic particles phenomenon.

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Figure 1. Types of the MESEP events according to the intensity-time profile. From upper left to right, type 1 and 2, from down left to right 3 and 4. Energy channels in MeV are listed on each channel. The vertical lines are : dashed for associated solar flares and arrow head for the associated CMEs.

Figure 2. The event of 11.11.2000, Anisotropy and He/p ration fit with a hidden CME during the time of the propagation of particles acceleration. Energy channels in MeV are listed on each channel. For explanation of the anisotropy diagrams, see text.

Figures are available on YSC home page (http://ysc.kiev.ua/abs/proc14_1.pdf).

Appendix

Table 1: List of MESEP events during solar cycle 23

Event		Associated eruptions		Type of event according to	
No	D.M.Y	CME	Solar flare	energy level	Intensity-time profile
01	12-15.07.96	4	2C	Mid	1
02	04-09.11.96	2	–	Low	1
03	27-28.11.96	2	–	Mid	2
04	28.11-03.12.96	3	2C,1M	High	2
05	07-08.02.97	3	–	Low	1
06	01-06.04.97	3	1C	High	4
07	07-12.04.97	2	1C	High	1
08	12-17.05.97	2	–	High	1
09	21-24.05.97	2	1M	High	1
10	20-22.09.97	3	1C	High	1
11	24-29.09.97	7	2M	High	1
12	12-14.10.97	2	–	Mid	1
13	21-24.10.97	5	1C	High	1
14	03-13.11.97	8	2X,5M,1C	High	3
15	13-16.11.97	5	1M	High	3
16	06-10.12.97	4	–	High	1
17	03-04.01.98	1	1M	low	1
18	25-31.01.98	5	1C,1M	High	1
19	20-26.04.98	6	1C,1M,1X	High	4
20	26.04-02.05.98	5	3M,1X	High	2
21	02-06.05.98	4	1C,2M,1X	High	4
22	06.05.98	2	1M,1X	High	2
23	09-10.05.98	3	3M	High	1
24	30-31.05.98	3	1C	High	2
25	02-03.06.98	7	1C	Mid	3
26	04-08.06.98	6	–	High	1
27	08-14.06.98	17	4C,2M	High	4
28	14-16.06.98	3	1C	Mid	1
29	16-22.06.98	13	1C,1M	High	1
30	22-24.06.98	4	–	Mid	2
31	20-23.10.98	2	1C	High	1
32	25-27.10.98	7	–	Mid	4
33	05-13.11.98	15	2C,9M	High	3
34	22-30.11.98	9	4M,5X	High	3
35	09-13.12.98	6	1C	Low	4
36	17-18.12.98	5	1M	Mid	4
37	19-21.12.98	2	1M	High	1
38	08-14.02.99	8	3C,2M	High	1
39	25-26.02.99	3	–	Mid	1
40	05-15.03.99	21	1C,2M	Mid	1
41	25-27.03.99	3	–	High	1
42	24-30.04.99	13	1M	High	1
43	03-27.05.99	25	2C,14M	High	3
44	27-30.05.99	4	1C	High	4
45	01-03.06.99	8	1C,1M	High	1
46	03-06.06.99	5	1M6	High	4
47	11.06.99	2	1C	High	1
48	24-27.06.99	6	1M	Mid	2
49	27-28.06.99	7	1C,1M	High	4
50	29.06-03.07.99	9	11M	High	4
51	03-06.07.99	6	1M	Mid	1
52	12-13.07.99	3	–	Mid	1
53	16-18.07.99	2	1C,2M	High	1
54	25-31.07.99	14	1C,7M	High	1
55	31.07-07.08.99	14	8M,1X	High	1
56	07-13.08.99	8	4C,2M	Mid	1
57	17-21.08.99	8	5C,6M	Mid	4
58	28-31.08.99	1	1C,2M,1X	High	4
59	02-04.09.99	3	2C	Mid	2
60	10-13.09.99	9	–	Mid	1
61	13-16.09.99	17	2C	High	1
62	19-20.09.99	5	1C	Mid	1
63	21-22.09.99	6	1C	Mid	1
64	13-14.10.99	2	–	Mid	4
65	14-22.10.99	13	1M,1X	High	1
66	22-24.10.99	2	1C	Mid	1
67	06-14.11.99	12	3C,12M	Low	1
68	15-23.11.99	6	1C,14M	High	4
69	28.11-03.12.99	1	4M	High	4
70	09-14.12.99	2	1C	Mid	3
71	20-26.12.99	8	3M	High	4

Event		Associated eruptions		Type of event according to	
No	D.M.Y	CME	Solar flare	energy level	Intensity-time profile
72	27-29.12.99	7	3M	High	1
73	30.12.99-02.01.00	8	–	Mid	4
74	09-11.01.00	–	2M	High	2
75	18-23.01.00	11	4M	High	2
76	27-31.01.00	9	–	High	1
77	09-16.02.00	21	3C,1M	High	1
78	17-23.02.00	14	1C,9M	High	1
79	04-08.04.00	13	4M	High	1
80	18-23.04.00	11	4M	High	2
81	23-26.04.00	12	–	High	4
82	27-30.04.00	7	3C	High	3
83	04-11.05.00	18	3M	High	2
84	11-14.05.00	11	2M	High	2
85	14-26.05.00	31	2C,12M	High	2
86	03-13.06.00	12	–	High	4
87	13-16.06.00	30	2C,11M,3X	High	4
88	16-21.06.00	12	1C,1M,1X	High	3
89	21-25.06.00	8	3M	High	1
90	25-28.06.00	10	2M	High	1
91	28-30.06.00	5	–	High	1
92	11-28.07.00	36	42M,3X	High	2
93	28.07-01.08.00	12	–	High	4
94	09-11.08.00	4	3C	High	1
95	12-20.08.00	24	1C,1M	High	2
96	04-07.09.00	4	1C,1M	Mid	3
97	07-11.09.00	9	1M	High	3
98	12-30.09.00	33	3C,12M,1X	High	1
99	10-15.10.00	6	2C,2M	High	4
100	16-24.10.00	8	4C,2M	High	4
101	29.10-08.11.00	19	3C,2M	High	2
102	08-24.11.00	39	1C,11M	High	4
103	24.11-13.12.00	31	4C,7M,5X	High	1
104	28.12.00-05.01.01	10	2C,3M	High	1
105	05-09.01.01	7	2C	High	1
106	21-28.01.01	8	3M	High	1
107	28.01-06.02.01	11	3C,2M	High	2
108	11-21.02.01	11	1C	High	1
109	26.02-05.03.01	14	2C	High	4
110	08-14.03.01	20	2C,4M	High	3
111	25-29.03.01	11	3C,11M	High	1
112	29.03-02.04.01	15	14M,1X	High	1
113	02-09.04.01	25	1C,11M,5X	High	3
114	09-15.04.01	15	1C,5M,2X	High	3
115	15-25.04.01	26	13M,1X	High	2
116	26.04-05.05.01	11	2C,5M	High	2
117	07-20.05.01	27	5C,5M	High	1
118	20-26.05.01	12	3C,3M	High	4
119	26-30.05.01	11	–	Mid	1
120	31.5-11.06.01	27	4M	High	1
121	11-30.06.01	43	5C,9M,1X	High	3
122	09-31.08.01	50	3C,18M,1X	High	1
123	04-09.09.01	6	1C,15M	Mid	4
124	12-14.09.01	5	1C,2M	High	1
125	15-17.09.01	4	7M	High	4
126	18-23.09.01	7	5M	High	1
127	24-30.09.01	17	1C,12M,1X	High	3
128	01-08.10.01	17	5C,5M	High	3
129	09-18.10.01	19	2C,2M	High	2
130	19-21.10.01	5	8M,2X	High	4
131	22-31.10.01	29	3C,16M,2X	High	1
132	02-04.11.01	1	1M	Low	4
133	04-16.11.01	14	2C,29M,1X	High	3
134	17-21.11.01	4	1M	High	3
135	22-30.11.01	12	1C,12M,1X	High	3
136	09-24.12.01	23	2C,15M,2X	High	2
137	26.12.01-09.01.02	23	3C,23M,1X	High	2
138	10-20.01.02	13	3C,11M	High	3
139	27-31.01.02	7	1C,1M	High	4
140	14-17.02.02	3	–	Mid	2
141	19-28.02.02	14	4C,12M	High	1
142	04-11.03.02	12	2C,2M	Mid	3
143	11-22.03.02	27	1C,9M	High	3
144	22-26.03.02	7	2C,1M	High	3
145	30.03-02.04.02	10	3M	Low	4
146	11-13.04.02	7	2M	High	4
147	14-15.04.02	6	4M	High	3

Event		Associated eruptions		Type of event according to	
No	D.M.Y	CME	Solar flare	energy level	Intensity-time profile
148	17-20.04.02	7	1M	High	1
149	21.04-15.05.02	50	1C,4M,1X	High	2
150	15-20.05.02	27	2C,6M	Low	2
151	20-22.05.02	3	1C,1M,1X	High	2
152	22-27.05.02	15	2C,1M	High	4
153	27.05-06.06.02	14	4C,7M	High	3
154	06-11.06.02	7	2C	Mid	4
155	04-06.07.02	6	2M	High	3
156	07-14.07.02	15	1C,7M	High	1
157	16-31.07.02	27	4C,16M,3X	High	2
158	03-08.08.02	14	1C,3M,1X	High	3
159	14-16.08.02	8	4M	High	1
160	16-21.08.02	22	1C,16M,1X	High	3
161	22-24.08.02	8	1C,7M	High	4
162	24-31.08.02	17	11M,2X	High	1
163	05-16.09.02	21	3C,6M	High	4
164	17-19.09.02	5	1C	Mid	1
165	23.09.02	2	–	Low	1
166	24.09.02	4	–	High	1
167	27-30.09.02	12	4M	High	1
168	05.10.02	1	2M	Low	1
169	13-25.10.02	32	2C,8M	High	1
170	28.10-06.11.02	34	2C,4M,1X	High	4
171	09-17.11.02	22	2C,8M	High	2
172	17-18.11.02	2	2C,2M	Low	4
173	21-24.11.02	7	–	Low	2
174	25.11-02.12.02	24	3C	High	1
175	08-18.12.02	14	6M	High	2
176	19-21.12.02	6	1C,2M	High	4
177	22-25.12.02	2	1M	High	2
178	30.12.02-03.01.03	7	–	Low	1
179	20-23.01.03	14	1C,2M	High	1
180	23-25.01.03	4	3M	Low	1
181	27-30.01.03	5	1C	High	1
182	01-03.02.03	4	–	Low	1
183	12-13.02.03	6	–	Low	1
184	20-23.02.03	5	2C	Low	1
185	23-26.02.03	4	–	Mid	4
186	13-17.03.03	5	–	Low	1
187	17-18.03.03	6	2M,1X	High	3
188	18-20.03.03	10	5M,1X	High	2
189	24-30.03.03	8	1C	Low	2
190	01-06.04.03	15	1C,1M	Mid	4
191	07-12.04.03	7	1C,1M	High	4
192	21-25.04.03	7	4M	High	2
193	25.04-02.05.03	20	6C,8M	High	4
194	06-09.05.03	5	2C	Low	1
195	27.05-03.06.03	20	3C,14M,3X	High	3
196	05-07.06.03	11	1M	Mid	4
197	09-11.06.03	4	11M,2X	Mid	2
198	11-13.06.03	1	14M,1X	High	1
199	15-28.06.03	14	5C,3M,1X	High	1
200	10-12.07.03	4	2C,2M	High	1
201	17-21.07.03	5	–	High	4
202	26.07-02.08.03	6	1C,3M	Mid	1
203	03-07.08.03	6	1M	Mid	2
204	08-10.08.03	3	1C	Low	1
205	19-21.08.03	4	2M	High	2
206	21-24.08.03	4	1C	Low	4
207	17-23.09.03	11	3C	Mid	1
208	04-05.10.03	8	1M	High	2
209	20-26.10.03	24	2C,2M,3	High	1
210	26-28.10.03	6	6M,1X	High	1
211	28-29.10.03	1	1X	High	3
212	29.10-02.11.03	5	1C,9M,1X	High	1
213	02-04.11.03	8	3M,3X	High	3
214	04-18.11.03	28	1C,11M,1X	High	2
215	18-30.11.03	21	2C,7M	High	2
216	02-11.12.03	8	1C,4M	High	3
217	11-23.12.03	12	–	Mid	2
218	26-27.12.03	2	1M	Low	1
219	01-18.01.04	30	1C,8M	High	1
220	18-28.01.04	17	1C,4M	Mid	2
221	01-03.02.04	4	–	Low	2
222	04-06.02.04	9	–	High	4
223	26.02-03.03.04	4	1M,1X	Mid	4
224	04-11.03.04	8	1M	Low	2

Event		Associated eruptions		Type of event according to	
No	D.M.Y	CME	Solar flare	energy level	Intensity-time profile
225	17-19.03.04	3	1C,2M	Low	2
226	21-23.03.04	3	1C	Mid	2
227	08-17.04.04	24	–	Low	2
228	20-25.05.04	6	–	Low	4
229	25-28.05.04	5	–	Low	4
230	02-04.06.04	5	–	Mid	1
231	04-06.06.04	3	–	High	4
232	06-17.07.04	10	1C,9M,5X	High	1
233	22-25.07.04	11	9M	High	1
234	25-29.07.04	7	8M	High	2
235	29.7-06.08.04	7	3C	High	3
236	13-17.08.04	2	17M,1X	Mid	4
237	18-22.08.04	7	1C,2M,1X	High	4
238	03-05.09.04	7	–	High	4
239	09-19.09.04	10	3C,3M	High	1
240	19-25.09.04	5	1C,1M	High	4
241	30-31.10.04	7	M,1X	High	2
242	01-03.11.04	4	1C,5M	High	4
243	05-19.11.04	24	8M,2X	High	1
244	03-12.12.04	11	1C	High	1
245	15.01-15.02.05	53	16M,5X	High	1
246	17-21.02.05	7	1M	High	1
247	26.02-05.03.05	6	–	Mid	2
248	06-10.03.05	6	–	Mid	2
249	14-16.03.05	2	1C	Mid	3
250	03-13.05.05	19	1C,7M	High	1
251	13-20.05.05	7	5M	High	3
252	26-29.05.05	4	1C,1M	Mid	1
253	31.5-03.06.05	3	3M	High	1
254	03-11.06.05	6	–	High	4
255	16-24.06.05	7	1C,1M	High	1
256	07-12.07.05	17	3C,2M	High	3
257	13-22.07.05	25	2C,9M,1X	High	2
258	24.7-07.08.05	24	3C,7M,1X	High	4
259	22-28.08.05	27	1C,4M	High	3
260	29-31.08.05	8	1C	High	4
261	04-24.09.05	27	4C,26M,10X	High	2
262	29.11-03.12.05	12	5M	Mid	3
263	18-20.12.05	3	–	Low	2
264	06-13.07.06	12	1M	High	2
265	16-21.08.06	6	2C	High	1
266	01-05.09.06	7	1C	Mid	1
267	06-16.11.06	13	1C	High	2
268	05-23.12.06	19	4C,5M,4X	High	3